Direction of the ice flow through Long Island during maximum extension of Laurentide Ice Sheet

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Introduction

The present model of the development of Long Island's moraines is not functional. It cannot explain: 1. the same cosmogenic age of Harbor Hill and the Ronkonkoma Moraines 2. the missing arch of the Connecticut Lobe on Long Island's moraines and 3. the differences between the South Shore and North Shore tills.

This study attempts to produce a model which would fit into this new data. The new model utilizes a pattern of deglaciation left by the recessional moraines in New England, the differences between the tills of the Western North Shore and South Shores of LI, and the glacial features of Long Island Sound (LIS).

Different sources for Western North Shore till of Long Island and for till of South Shore of Long Island

The island is all covered by a till (King C., Mion L., Pacholik W., Hanson G, H., 2023). This veneer of till is not covered by an outwash. The lack of the superimposed till suggests that there were no glacial retreats followed by glacial advances. This observation suggests that the section of the Laurentide Ice Sheet, which was covering Long Island (LI) and most likely the main part of Long Island Sound (LIS), became enactive and melted shortly after the ice sheet reached its maximum. This interpretation suggests the transgressional origin of the LI moraines.

There are two major provinces of till on LI, the North Shore till and the South Shore till south of the Ronkonkoma Moraine. The differences in appearance between the North Shore till and the South Shore till lead the public to believe that the South Shore is strictly an outwash plain. The most visible difference between these two sediments is that the South Shore Till does not contain boulders and cobbles are extremely rare. These cobbles of the South Shore are generally quartz monzonites and granites of Avalonian Terrane (eastern LIS and eastern Connecticut).

There are no comprehensive studies done on Long Island till. That is why for the purpose of this investigation I used a classification of LI soils (Bowman I, 1911). On the LI soil map different types of soils can be correlated to different types of till (Figure 1). Going from North Shore down south there are: stony loams - tills with boulders and cobbles, pebbly till mapped as gravel loams, coarse sandy loams –coarse sandy tills, and eventually, by the Great South Bay, sandy tills mapped as sandy loams.

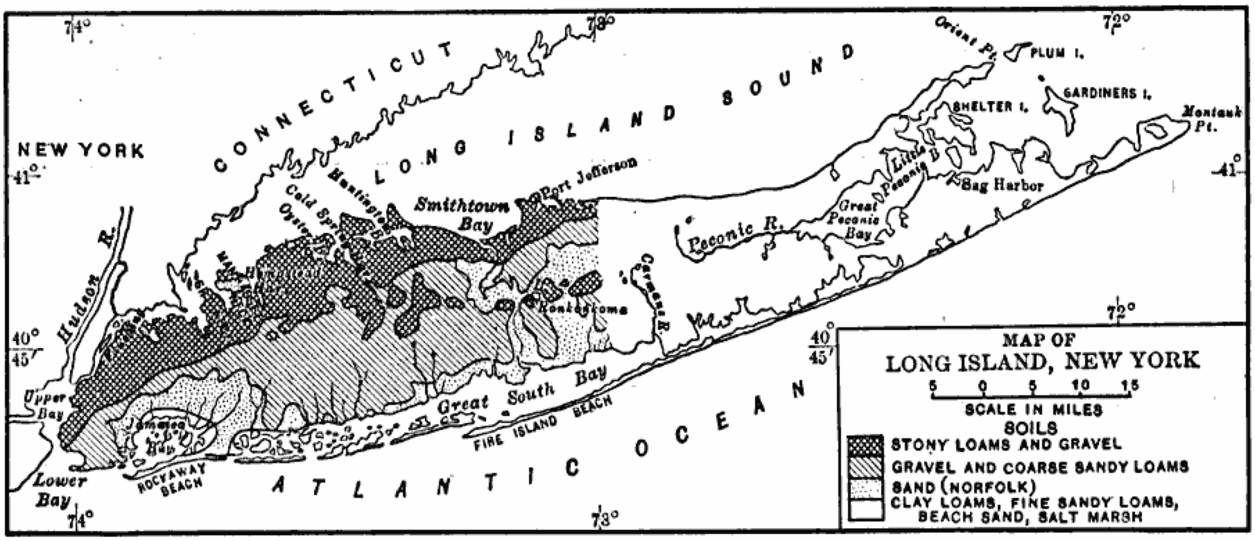


Figure 1. Soils of Long Island, 1911. The map shows the four broad soil types of Long Island, keyed to show areas of stony loams and gravel, coarse sandy loams and gravel, sand, and sandy loams with beach sands or salt marsh.

When cobbles are removed from the Stony Brook till (North Shore till) its grain percentage distribution does not differ from the percentage distribution of the South Shore till from Sayville (South Shore till by the Great South Bay) (Figure 2).

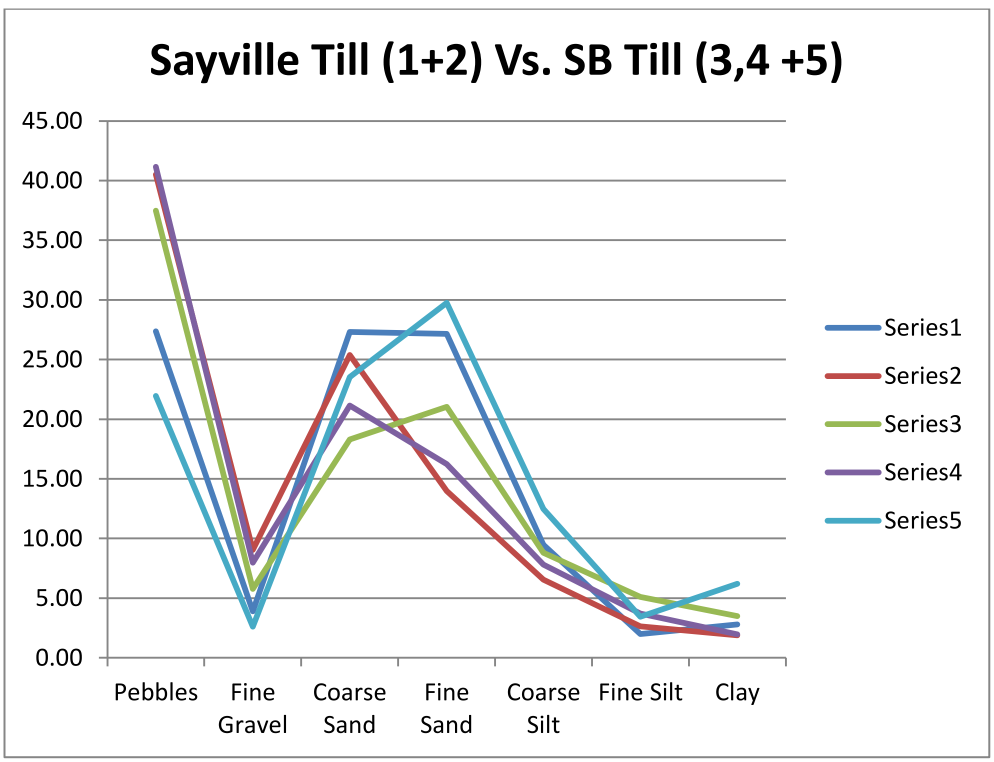
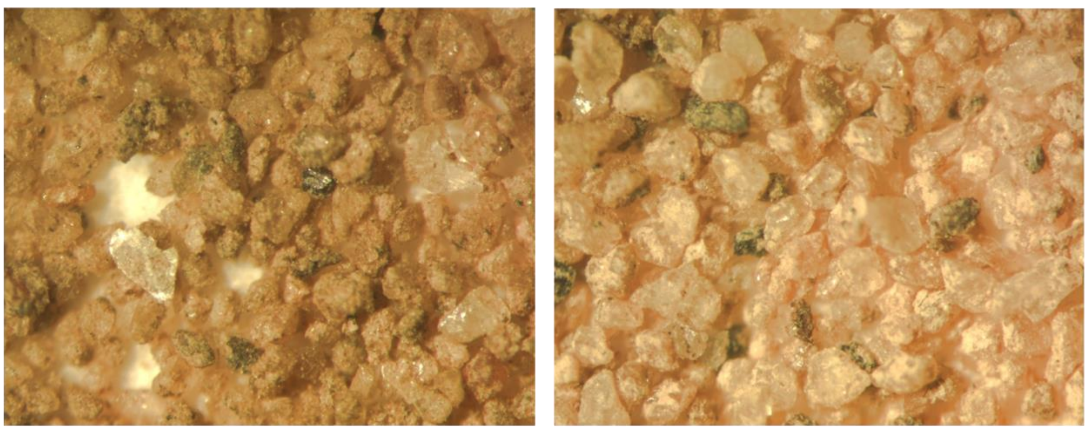


Figure 2. Percentage distribution of grain size from North Shore till of Stony Brook, and South Shore till of Sayville.

The biggest difference between the tills from North and South comes from their colors. The North Shore till of Western Long Island is dark and the South Shore till is light yellow (Figure 3). The dark appearance of the North Shore till suggests a rock source with a high percentage of mafic minerals, which can be matched to the Acadian Terrane of western Connecticut, and light color South Shore till can be correlated to the felsic source of the Avalonian Terrane of eastern Connecticut. This observation suggests that the South Shore drift came from the north east – diagonally across LI – and the North Shore drift of western LI came directly from the north.

Stony Brook silt | **Sayville silt**



Product of sub glacial erosion of rocks with high percentage of biotite, hornblende gneisses of Acadian Terrane

Product of sub glacial erosion of rocks with high percentage of granites and quartz monzonites of Avalonian Terrane

Figure 3. Differences of colors between silts from tills of different provinces of rock source, the Acadian Terrane and the Avalonian Terrane.

Connecticut Lobe (CL)

The USGS map of New England deglaciation (Stone, J.R., Schafer, J.P., London, E.H., Lewis, R.L., DiGiacomo-Cohen, M.L., Thompson, W.B., 1998, Figure 4) shows the sequence of moraines which indicates the position of the Hudson (HL) and Connecticut Lobes (CL). By tracing the positions of these bulging lobes on the consecutive moraines, we can locate the main streams of ice in the Laurentide Ice Sheet. The stream pattern for the Connecticut Lobe can be traced from Canada through hundreds of miles south until it reaches the Harbor Hill Moraine (HHM) or the Ronkonkoma Moraine (RM). Surprisingly HHM and RM do not show bulging caused by the CL stream of ice. These straight line moraine boundaries in locations where the CL bulge would be expected are unexplained. Mapping of these moraines as straight lines, in locations where bulging of the lobe should be present, denies the physics of ice flow dynamics. This observation suggests that the moraine's lines of HHM and RM on LI should be reassessed. The new moraine's lines should utilize the glacial features of the Long Island Sound basin.

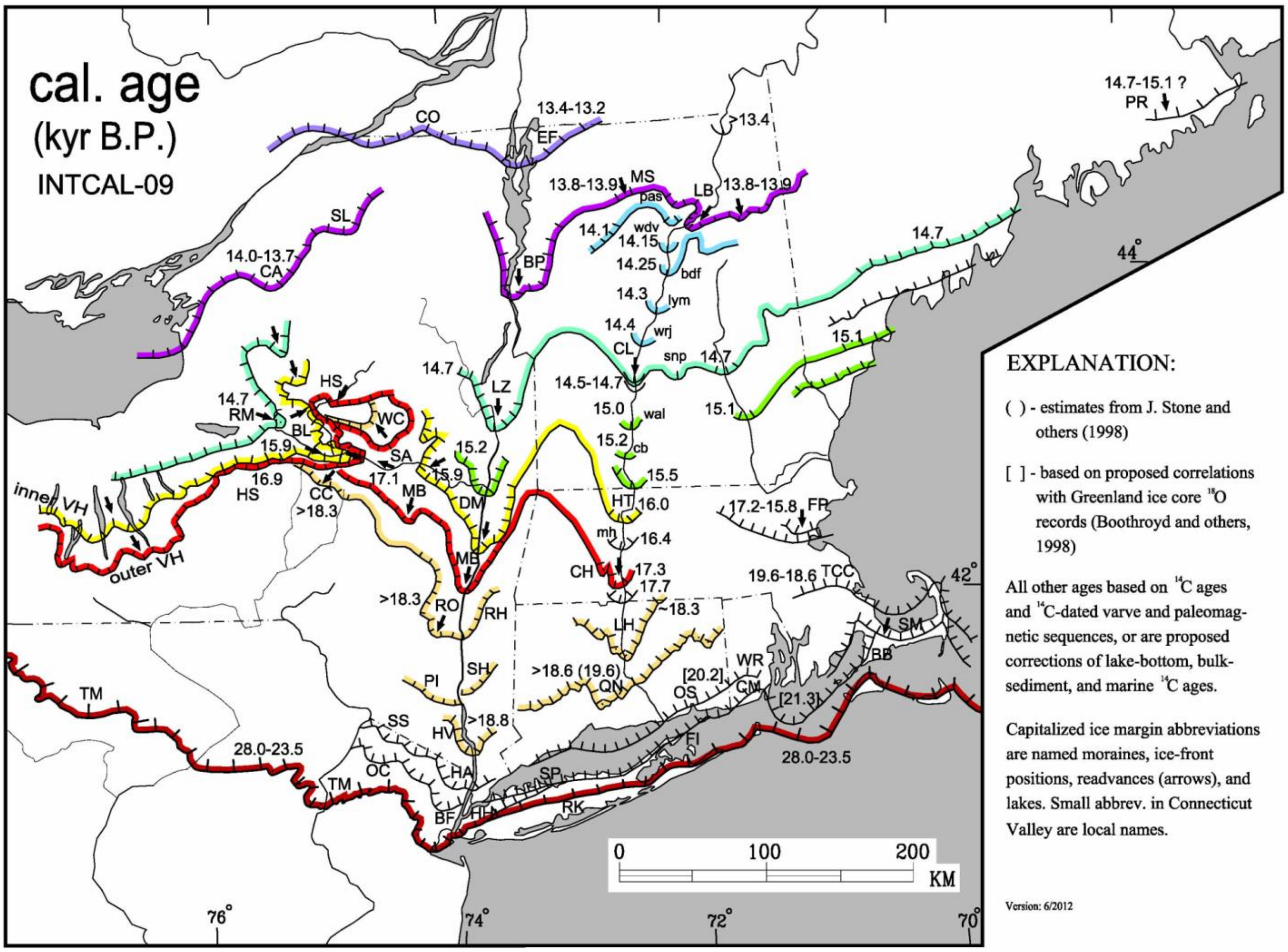


Figure 4. Calibrated ages of ice margins during ice recession in the northeastern U.S. The calibrated ages on the map are tabulated in thousands of years before 1950 AD (cal kyr BP). United States Geological Survey, Open-file Report 98-371, 1 sheet, 77 p.

The stratigraphy of LIS's topographic futures resembles the stratigraphy of LI's moraines (Newman, 1977, Poppe L.J., Paskevich V.F., Lewis R.S., and M.L. DiGiacomo-Cohen M.L., 1981 - 1990). Generally, they are stratified sands topped with course sediments. The only difference between LIS's and LI's course sediments is that the course sediments which veneer LI's moraines are tills. This difference disappears when wave erosion is taken into consideration. For example, right now the Harbor Hill Moraine is eroded by wave action of LIS and as a result, what is left on the beach, is stratified sand covered by course sediment. During the transgression of the ocean into the LIS basin all of LIS's moraines where eroded in a similar way. Based on the stratigraphy of these forms, they should all be labeled as moraines.

However, only forms which agreed with the direction of elongation of LI's moraines, been classified this way (Figure 5a). All glacial forms with an N-S elongation on LIS's floor are mapped as outwash heads or outwash deltas (Figure 5a and 5b). In this study, all LIS's bottom forms with a common stratigraphy, (as described above), are classified as moraines in order to explain the flow of the CL ice stream.

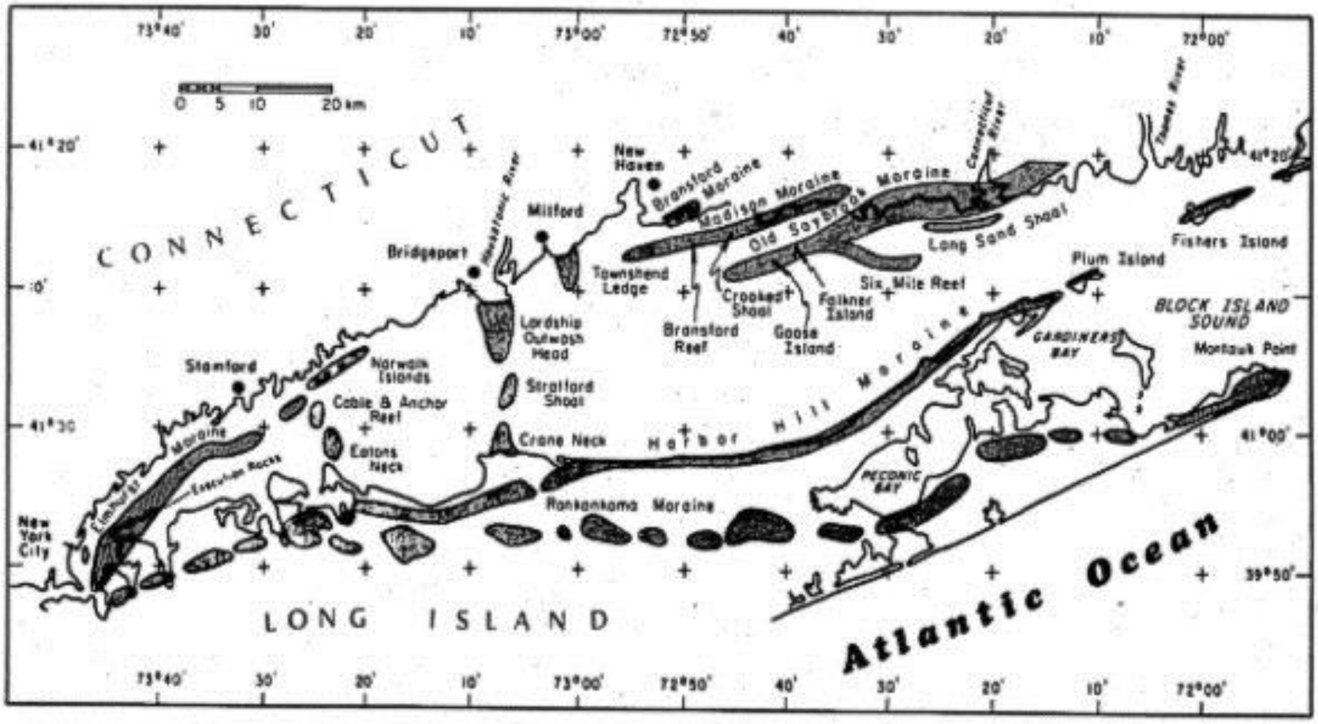


Figure 9. Late Wisconsin-age Harbor Hill and Ronkonkoma Moraines extend along Long Island, but there is good evidence for younger moraine segments and outwash features to the north in Long Island Sound and along the Connecticut coast (discussed in text).

Figure 5a. Classification of glacial features on the bottom of Long Island Sound and Long Island., Newman, 1977.

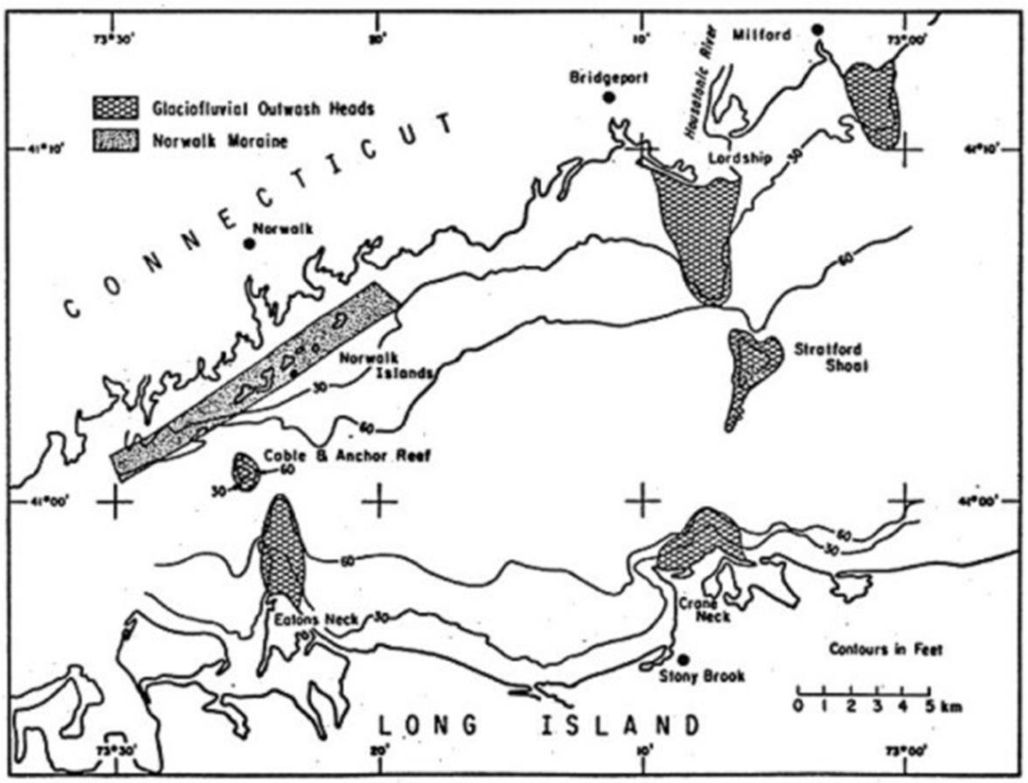


Figure 11. The Norwalk Islands of Connecticut are remnants of a late Wisconsin moraine extending discontinuously from Queens County, Long Island, northeast to the New Haven area. The Lordship and Milford outwash deltas associated with that moraine and the positive relief features at Cable and Anchor Reef, Eatons Neck, Stratford Shoal, and Crane Neck also appear to have a glacial origin.

Figure 5b. USGS map of glacial features of western Long Island Sound., Geological Framework Data from Long Island Sound, 1981-1990: A Digital Data Release

Mapping a new sequence of moraines which include the missing bulge of Connecticut Lobe (CL)

The reconstruction of the moraines' boundaries is based on the assumption that a stream of the CL did not change position during the transgression and recession of the Laurentide Ice Sheet.

1. The line of transgressional moraines of south-eastern Connecticut (Mystic, Old Saybrook, Hammonassett – Ledyard) should extend SW into LIS and then turn N through the Milford Outwash Delta (this turn makes the bulge of the CL), and then SW, in order to follow the pattern of recession in New England (Figure 6. Moraine line nr. 1.).
2. The transgressional HHM should have a few stages of development because the glacier would not push south until the LIS depression filled with ice.
   Stages of HHM:
   A. First the front of the CL reached eastern LI. The tip of the CL was located by the Port Jefferson area. From that point the line of the glacial front moved north through the Stratford Shoal, and the Lord Sheep Outwash. Afterward the line turned SW through

the Norwalk Moraine and down to the Hudson Lobe (HL) in order to agree with the New England pattern of ice flow (Figure 4). From this position, the stream of CL started to fill up the LIS depression and the CL shifted westward. First, the ice which crept west left behind the moraine deposits of Crane Neck and the Crane Neck Outwash Head directly north of Crane Neck (Figure 6. Moraine line number 2. Figure 5a and 5b).

B. Ice from the CL stream which was filling the westward LIS basin had its front by Eaton's Neck. The northward turn of the lobe went through the Cable and Anchor Reef (Norwalk Shoal), turned on the Norwalk Moraine SW and, then followed the HL pattern (Figure 6. Moraine line number 3. Figure 5a and 5b). The smaller westward transgression of the CL could leave deposits at Lloyd Neck.

3. At this point, the stream of the CL overflowed the LIS basin and formed the RM. The tip of the CL arch was located in the middle of the island around West Hills. The westward side of the CL arch passed NW through the vicinity of Locust Valley to the Elmhurst Moraine where the moraine line turned SW and followed the pattern of the HL (Figure 6. Moraine line number 4. Figure 5a and 5b).
4. The next transgressions of ice were caused by the HL ice stream. The line of the Elmhurst Moraine was rotated from the SW-NE direction to the SWW-NEE one, and formed a series of moraine lines mapped by Sirking, 1996 (section of HHM between Upper Bay and Syosset), (Figure 6. Moraine line number 5).

Figure 6. Sequence of moraines (lines number: 1, 2, 3, 4, 5, and 6) in Long Island Sound and Long Island regions which shows flow of Connecticut Lobe ice stream (arrows indicated by number 7) and dreg of vicinity ice (arrows number 8 and 9). Overlay map: Google Earth map, Quaternary geologic map of Connecticut and Long Island Sound Basin (Stone and others, 2005), Classification of glacial features on the bottom of Long

Island Sound and Long Island., Newman, 1977, USGS map of glacial features of western Long Island Sound., Geological Framework Data from Long Island Sound, 1981-1990: A Digital Data Release, and Sea-Floor Geology and Topography Offshore in Northeastern Long Island Sound, U.S. Geological Survey Open-File Report 2013–1060.

Terminal Position of Laurentide Ice Sheet on Long Island

The clues about the maximum extension of the Laurentide Ice Sheet, on LI came from the Jamaica Bay area, coarse Pleistocene sediments from the ocean bottom south of Long Beach, and the orientation of the RM.

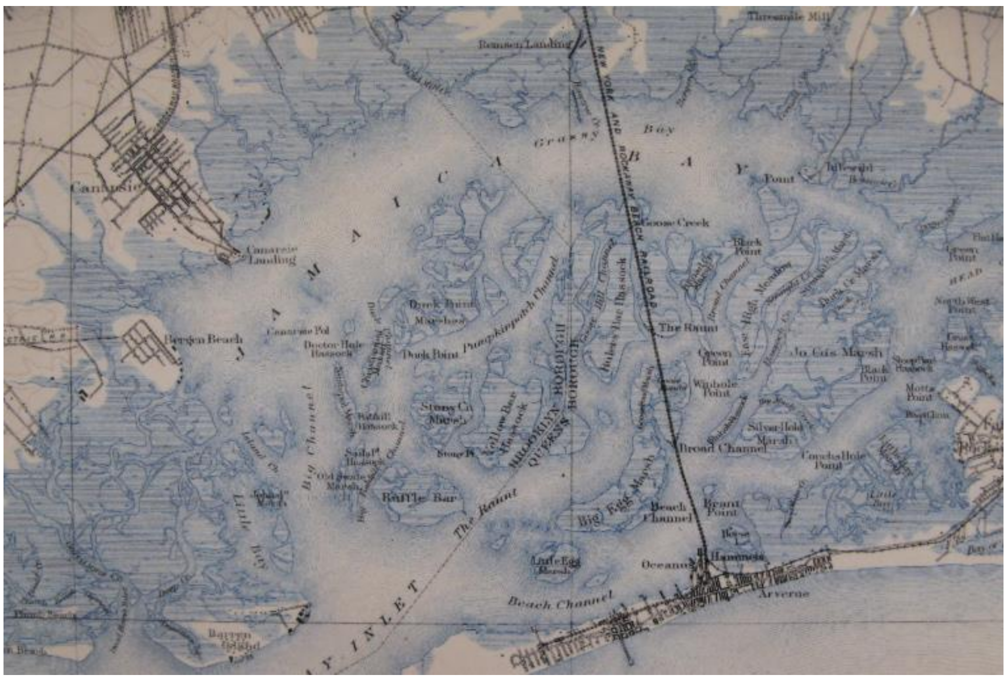
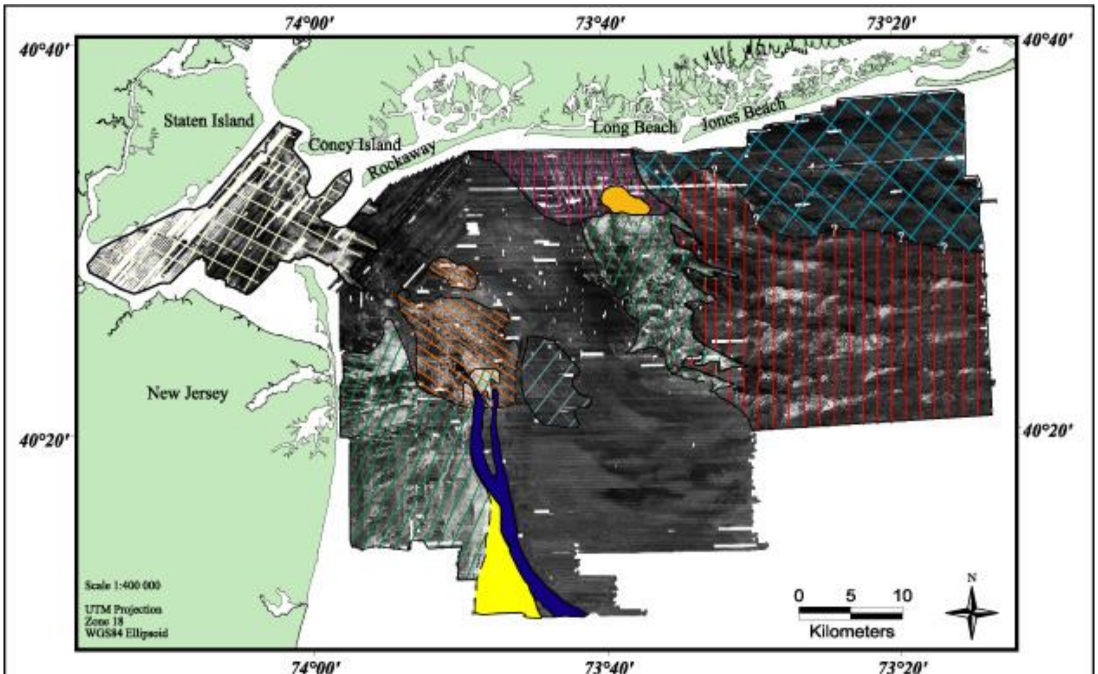


Figure 7. Map of Jamaica Bay, US Geological Survey, 1898.

The drainage pattern of Jamaica Bay is concentric and does not agree with the general NW-SE slope of LI (Figure 7). This observation infers that Jamaica Bay formed as a cove between the ice of the HL and the CL. The outline of the cove (till and outwash interface) marks the position of the terminal extension of the late Laurentide Ice Sheet. The eastern margin of the cove dips south and then curves around the Pleistocene gravelly sand deposits south of Long Beach (Poppe L.J., McMullen K.Y., Ackerman S.D., Glom K.A., 2013, Figure 8). This gravelly sand appears to be the remains of reworked south shore till. The glacial margin should then follow the pattern of the RM. This pattern brings the glacial terminus to the vicinity of Jones Beach and then moves it eastward back into the ocean (Figur 6. Moraine line number 6).



Explanation

High-backscatter, outcropping, early Tertiary/late Cretaceous coastal plain strata and associated reworked gravelly lag deposits. Low-backscatter, reworked Quaternary deposits are common (see Figure 10).

High-backscatter Pleistocene gravelly sand deposits.

Pleistocene fluvioglacial gravelly sands reworked into a series of low-amplitude, fine sand, transverse bedforms. Gravelly sand forms the high-backscatter lineations and fine sand is displayed as low-backscatter (see Figure 6).

Low-backscatter Holocene sand ridges (find sand) with reworked, high-backscatter early Tertiary/late Cretaceous coastal plain strata and associated reworked gravelly lag deposits exposed in the troughs (see Figure 12).

Low-backscatter, low-amplitude, Holocene sand ridges (fine sand) with reworked, high-backscatter Pleistocene coarse sand exposed in the troughs.

Low-backscatter Holocene fine sand.

High-backscatter Holocene coarse sand.

Holocene deposit in Raritan Bay. Sediment textural data for this area are not available.

Holocene sand waves (see Figure 15).

Anthropogenic disposal material (dredge spoils and construction refuse) (see Figure 13).

Holocene (modern) silty deposit.

Contact
Long dash with question mark approximate location

Figure 5. Sidescan-sonar imagery collected within the New York Bight Apex, and geologic interpretation. High backscatter is represented by light tones, low backscatter by dark tones.

Figure 8. Sea-Floor Geology and Topography Offshore in Northeastern Long Island Sound, U.S. Geological Survey Open-File Report 2013–1060.

The terminal moraine of the LI region most likely did not develop due to the following conditions:

1. The down slope push over the sandy outwash did not favor the formation of push moraine.
2. The lack of boulders or cobbles which could form dump moraine.
3. Glacial drainage effectively removed fine sediments from glacial terminus.
4. Short duration of ice sheet coverage.

Reconstruction of ice flow pattern through Long Island

The bends of the CL on each consecutive moraine line indicates the location of the fastest moving ice stream of the CL through LI (Figure 6. The arrows number 7). This stream moved diagonally across LI from the Port Jefferson region to the area south of Long Beach. The faster moving ice stream (low pressure system) dragged the slower moving ice of its vicinity (relatively high pressure system) inward toward the main stream (Bernoulli's Law). This pattern of ice motion explains drift of mafic material (North Shore till) from the Acadian Terrane (Western Connecticut) directly south to the northern part of western LI (Figure 6. The arrow number 9), and felsic material (south shore till) from the Avalonian Terrane of Eastern Connecticut and eastern LIS to the South Shore of LI (Figure 6. The arrow number 8).

Conclusion

1. LI moraines and glacial features of LIS basin reveal a new pattern of moraines, which trace the motion of the CL ice stream through LI.
2. The Connecticut Lobe moved diagonally through Long Island from Port Jefferson toward Long Beach.
3. The faster moving ice stream of the CL created dregs of ice from the vicinity, causing the movement of ice from the Acadian Terrane directly south to LI, and ice from the Avalonian Terrane south west across LI to the South Shore.
4. During glacial maximum, the Jamaica Bay area was ice free and separated Hudson and Connecticut Lobes.
5. The terminal extension of the Wisconsin glacier on LI can be inferred from the outwash boundary of Jamaica Bay, course sediments south of Long Beach, and the pattern of moraines in that region.
6. The Long Island terminal moraine did not form.

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